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(71) Applicant: WARNER-LAMBERT COMPANY [US/US]; 201 Tabor Road, Morris Plains, NJ 07950 (US).

(72) Inventors: HOLLER, Tod, Paul; 2375 Placid Way, Ann Arbor, MI 48105 (US). MEYER, Annette; 4577 Clifford Road, Brighton, MI 48116 (US). NABEL, Gary, Jan; 3390 Andover, Ann Arbor, MI 48105 (US). POST, Leonard; 3695 Pheasant, Ann Arbor, MI 48103 (US).

(74) Agents: RYAN, Andrea, M.; Warner-Lambert Company, 201 Tabor Road, Morris Plains, NJ 07950 (US) et al.

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(54) Title: METHOD OF USING TRANSDOMINANT NEGATIVE RETROVIRAL INTEGRASE IN THE TREATMENT OF RETROVIRAL INFECTION

(57) Abstract

A method of using a transdominant negative integrase gene to make at least one cell resistant to a retroviral infection which includes retroviral infections resulting from HIV; a method for introducing a transdominant negative integrase gene into at least one mammalian cell to make said cell resistant to a retroviral infection as well as vectors, cells, and methods of constructing same useful in the aforementioned methods; a method of treating AIDS comprising administering to a patient an effective amount of a transdominant negative integrase gene alone or combined with agents useful for gene therapy inhibition of HIV, antiviral agents, or interleukin-2; and pharmaceutical delivery methods which include a transdominant negative integrase gene alone or combined with agents useful for gene therapy inhibition of HIV, antiviral agents, or interleukin-2.

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METHOD OF USING TRANSDOMINANT NEGATIVE RETROVIRAL INTEGRASE IN THE TREATMENT OF RETROVIRAL INFECTION

BACKGROUND OF THE INVENTION

The present invention relates to a medical method of treatment. In particular, the present invention concerns the use of a transdominant negative integrase gene to make at least one mammalian cell resistant to a retroviral infection, to methods for their production, to pharmaceutical delivery methods which include these genes, and to pharmaceutical methods of treatment. More particularly, the novel transdominant negative integrase gene alone or combined with another gene that confers protection from human immunedeficiency virus (HIV) such as, for example, a transdominant negative rev gene and/or a ribozyme that cleaves HIV ribonucleic acid (RNA) is useful in treating acquired immunedeficiency syndrome (AIDS).

AIDS results from HIV infection which depletes $CD4^+$ T cells. Currently, there is no effective treatment for AIDS. One of the most attractive and least exploited targets for the therapy of AIDS is the viral integrase (Brown P.O., "Integration of Retroviral DNA". In: Current Topics in Microbiology of Immunology, 157:19-48 (1990)). The life cycle of retroviruses is dependent on integration into the host chromosome. For HIV, integration is necessary for viral replication (LaFemina R.L., et al., Journal of Virology, 66:7414-7419 (1992) and Sakai H., et al., Journal of Virology, 67:1169-1174 (1993)). This process is mediated by integrase, a viral protein. One approach to inhibition of the essential integration process is to express some form of integrase that will

block the integrase function of the incoming HIV. This is based on the concept of "pathogen-derived resistance" disclosed by Sanford J.C. and Johnston S.A., J. Theor. Biol., 113:395-405 (1985). Pathogen-derived resistance is based on the strategy that expression of certain genes from pathogens inhibit replication of such pathogens. Various examples of this concept have been disclosed including: retroviral envelope genes (Robinson H.L., et al., Journal of Virology, 40:745-751 (1981)); coat protein genes of plant viruses (Wilson T.M.A., Proc. Natl. Acad. Sci. USA, 90:3134-3141 (1993)); envelope glycoprotein genes of herpes viruses (Petrovskis E.A., et al., Journal of Virology, 62:2196-2199 (1988)); transdominant negative HIV rev (Malim M.H., et al., Cell, 58:205-214 (1989)); over-expression of HIV tar sequences as "decoys" (Sullenger B.A., et al., Cell, 63:601-608 (1990)); and transdominant negative mutants of HIV gag. In the case of HIV, this concept of pathogen-derived resistance was later termed "intracellular immunization" (Baltimore D., Nature, 335:395-396 (1988)).

However, prior to the present invention, there was no suggestion that retroviral integrase could be made to exert a transdominant negative phenotype. In fact, since integrase enters a cell with the virion and is presumed to remain part of the preintegration complex, it was regarded by many as an unlikely candidate for being amenable to interference by a transdominant negative mutant. In a recent review on gene therapy of AIDS (Yu M., et al., Gene Therapy, 1:13-26 (1994)), many possibilities were discussed with no mention of integrase as a target. Additionally, prior to the present invention, there was no good technology for exploring the possibility of a transdominant negative integrase. Retroviral integrases are made as part of polyprotein precursors (the "gag-pol precursor") in

infected cells. There is no natural expression of a retroviral integrase in a mammalian cell without many other viral proteins that are part of the precursor. Although there is a report of expression of Rous sarcoma virus integrase alone (Mumm S.R., et al., Virology, 189:500-510 (1992)), expression of HIV integrase has been problematic. This problem has been attributed to a rev-responsive element within the integrase gene (Cochrane, et al., J. Virol., 65:5305-5313 (1991)). Holler T.P., et al., Gene, 136:323-328 (1993) reported the synthesis of genes coding for wild-type ("NdeI") and an inactive mutant ("D116N:) integrase for expression in *E. coli*.

Thus, an object of the present invention is the expression of HIV integrase in mammalian cells. Efficient expression of HIV integrase was achieved in the present invention by employing a synthetic gene for expression in mammalian cells (Seq ID No.: 1). That this was successful was an unpredictable and surprising result, since the synthetic gene used was synthesized to optimize codon usage for the bacterium *E. coli*. Bacterial genes could have sequences recognized by mammalian cells as splice sites or methylation sites for inactivation of the gene, making the successful expression of a bacterial gene in mammalian cells highly unpredictable.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a method of using a transdominant negative integrase gene to make at least one cell resistant to a retroviral infection.

In a preferred embodiment of the first aspect of the invention, the retroviral infection is selected

from the group consisting of: HIV; HTLV I; HTLV II; equine infections anemia virus; bovine leukemia virus; murine retrovirus; and avian leukosis virus, and the cell is selected from the group consisting of a mammalian cell and an avian cell.

In a most preferred embodiment of the first aspect of the invention, the retroviral infection is HIV and the cell is a human cell.

In a second aspect, the present invention is directed to a method for introducing a transdominant negative integrase gene into at least one mammalian cell to make said cell resistant to a retroviral infection, comprising introducing the DNA into at least one mammalian cell by a process of delivery selected from the group consisting of:

a) use of calcium phosphate co-precipitation;
b) in a complex of cationic liposomes:
c) electroporation;
d) receptor mediated endocytosis;
e) naked DNA;
f) transduction by a viral vector; and
g) particle-mediated gene transfer (Cheng L., et al., Proc. Natl. Acad. Sci. USA, 90:4455-4459 (1993) and Yang N-S., Critical Reviews in Biotechnology, 12:335-356 (1992)).

In a preferred embodiment of the second aspect of the invention, the transdominant negative integrase gene is HIV integrase and the mammalian cell is a human cell.

In a most preferred embodiment of the second aspect of the invention, the human cell is selected from the group consisting of a $CD4^+$ T lymphocyte, a monocyte, and a hematopoietic progenitor cell, and the viral vector is selected from the group consisting of: retrovirus; adenovirus; adeno-associated virus; and herpes virus.

In a third aspect, the present invention is directed to a method for introducing a transdominant negative integrase gene into at least one mammalian cell to make said cell resistant to a retroviral infection comprising inserting said transdominant negative integrase gene into a vector and expressing transdominant negative integrase in said at least one mammalian cell.

In a preferred embodiment of the third aspect of the invention, the transdominant negative integrase gene is HIV integrase; the vector is selected from the group consisting of: pRSV/IN-NdeI and pRSV/IN-D116N; and the mammalian cell is 293-CD4.

In a more preferred embodiment of the third aspect of the invention, the transdominant negative integrase gene is HIV integrase; the vector is pRSV/IN-NdeI; and the mammalian cell is 293-CD4.

In a most preferred embodiment of the third aspect of the invention, the transdominant negative integrase gene is HIV integrase; the vector is pRSV/IN-NdeI; and the mammalian cell is a human cell selected from the group consisting of a $CD4^+$ T lymphocyte, a monocyte, and a hematopoietic progenitor cell.

In a fourth aspect, the present invention is directed to a method of constructing the pRSV/IN-NdeI vector comprising inserting the HIV integrase gene into the pRcRSV vector to afford the pRSV/IN-NdeI vector.

In a fifth aspect, the present invention is directed to a vector for production of HIV transdominant negative integrase comprising a DNA sequence encoding HIV integrase.

In a preferred embodiment of the fifth aspect of the invention, the vector is selected from the group consisting of pRSV/IN-NdeI and pRSV/IN-D116N.

In another preferred embodiment of the fifth aspect of the invention, the vector is pRSV/IN-NdeI.

In a more preferred embodiment of the fifth aspect of the invention, the DNA sequence contains a substantial number of codons different from the natural codons, preferably 10 or more codons different from the natural codons.

In a most preferred embodiment of the fifth aspect of the invention, the DNA sequence is Seq ID No.: 1 or a DNA sequence containing 10 or less codons different from Seq ID No.: 1 or a fragment thereof that encodes at least 150 amino acids; and expression is carried out in a eukaryotic cell, preferably a mammalian cell.

In a sixth aspect, the present invention is directed to the synthetic gene of Seq ID No.: 1 or a synthetic gene having a DNA sequence containing 10 or less codons different from Seq. ID. No.: 1 or a fragment thereof that encodes at least 150 amino acids.

In a seventh aspect, the present invention is directed to a highly transfectable cell line which is transduced to express human CD4.

In a most preferred embodiment of the seventh aspect of the invention, the highly transfectable cell line is 293-CD4.

In an eighth aspect, the present invention is directed to a method of constructing a 293-CD4 cell comprising inserting the CD4 coding sequence into a vector and transfecting the vector into 293 cells.

In a most preferred embodiment of the eighth aspect of the invention, the vector is RSV-CD4.

In a ninth aspect, the present invention is directed to a method of preparing a retroviral integrase comprising inserting a synthetic integrase gene into a vector and expressing said vector in a mammalian cell.

In another preferred embodiment of the ninth aspect of the invention, the retroviral integrase is HIV integrase.

In a more preferred embodiment of the ninth aspect of the invention, the synthetic integrase gene contains a substantial number of codons different from the natural codons, preferably 10 or more codons different from the natural codons.

In a most preferred embodiment of the ninth aspect of the invention, the synthetic integrase gene is Seq ID No.: 1 or a DNA sequence containing 10 or less codons different from Seq ID No: 1 or fragment thereof that encodes at least 150 amino acids.

A transdominant negative integrase gene could be delivered (by a retrovirus or other gene delivery method) to $CD4^+$ T cells from an HIV-infected patient ex vivo, then re-introduced into the patient. This would give the patient a population of T cells that would be resistant to infection by HIV. Additionally, a transdominant negative integrase gene could be delivered (by a retrovirus or other gene delivery method) to hematopoietic progenitor cells. Such cells can be derived from bone marrow or from peripheral blood after stimulation by a cytokine such as, for example, G-CSF. These transduced cells are then reintroduced into the patient. This would give a population of hematopoietic cells, including $CD4^+$ T cells that would be resistant to HIV.

Use of a transdominant negative integrase gene as a method of treatment of AIDS is based on the following scientific rationale:

1. Integrase is an essential protein for HIV infection. Genetic analysis of HIV integrase mutations (LaFemina R.L., et al., Journal of Virology, 66:7414-7419 (1992) and Sakai H., et al., Journal of Virology, 67:1169-1174 (1993)) shows that integrase is essential for HIV infection to proceed. Additional genetic analysis by Shin, C-G., et al., Journal of Virology,

68:1633-1642 (1994) shows that changes in integrase can have pleiotropic effects on a variety of steps in the HIV life cycle. Although we do not yet know the step in the HIV life cycle where the dominant negative integrase is having its effect, it is clearly a vulnerable target for interfering with replication of virus.

2. Cell culture results where HIV replication is blocked is the accepted criterion by the AIDS research community and regulatory authorities for clinical testing. This includes cell culture effect of transdominant negative mutants of retroviral proteins, as exemplified by the approval of clinical testing of rev M10 (Nabel G., et al., Human Gene Therapy, 5:79-92 (1994)).

3. Transdominant negative genes active in cell culture provide pathogen-derived resistance at the level of an intact multicellular organism. Examples include retroviral envelope genes and plant virus coat protein genes (Robinson H.L., et al., Journal of Virology, 40:745-751 (1981); Wilson T.M.A., Proc. Natl. Acad. Sci. USA, 90:3134-3141 (1993)).

Thus, in a tenth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene.

The transdominant negative integrase gene might advantageously be used in combination with any of a variety of other agents useful for gene therapy inhibition of HIV (Yu M., et al., Gene Therapy, 1:13-26 (1994) and Yamada O., et al., Gene Therapy, 1:38-45 (1994)).

Thus, in a eleventh aspect, the present invention is directed to a method of treating AIDS in a patient

comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with one or more agents selected from the group consisting of:

a) a transdominant negative gene such as, for example, a transdominant negative rev gene, a transdominant negative tat gene, a transdominant negative gag gene, a transdominant negative env gene, a transdominant negative vpx gene, and the like;

b) a soluble(s) CD4 gene such as, for example, a sCD4 gene, a sCD4-KDEL gene, and the like;

c) an intracellular antibody;

d) an interferon-inducible gene such as, for example, a RBP9-27 gene and the like;

e) a RNA decoy gene such as, for example, HIV-1 TAR, HIV-1 RRE, and the like;

f) an antisense RNA; and

g) a ribozyme such as, for example, a hammerhead ribozyme, a hairpin ribozyme, and the like.

Preferably, the transdominant negative integrase gene might advantageously be used in combination with other transdominant negative HIV genes, for example, a rev gene (e.g., the rev M10 of Malim M.H., et al., Cell, 58:205-214 (1989)) and/or ribozymes that cleave HIV RNAs (Yamada O., et al., Gene Therapy, 1:38-45 (1994)). This would enable a greater degree of efficacy than would be achieved by any one gene.

Thus, in a twelfth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a transdominant negative rev gene.

In a most preferred embodiment of the twelfth aspect of the invention, the transdominant negative rev gene is rev M10.

In a thirteenth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a ribozyme that cleaves HIV RNA.

In a fourteenth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a transdominant negative rev gene and a ribozyme that cleaves HIV RNA.

In a fifteenth aspect, the present invention is directed to a pharmaceutical delivery method adapted for administration to a patient in an effective amount of an agent for treating a retroviral infection comprising a transdominant negative integrase gene and a suitable viral or nonviral delivery system.

In a preferred embodiment of the fifteenth aspect of the invention, the pharmaceutical delivery method is adapted for ex vivo or in vivo delivery.

In a most preferred embodiment of the fifteenth aspect of the invention, the pharmaceutical delivery method is directed to therapeutic or prophylactic administration.

In a sixteenth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with an antiviral agent.

In a preferred embodiment of the sixteenth aspect of the invention, the antiviral agent is selected from the group consisting of a nucleoside or a nonnucleoside reverse transcriptase inhibitor, a HIV protease inhibitor, and a tat inhibitor.

In a most preferred embodiment of the sixteenth aspect of the invention, the reverse transcriptase inhibitor is selected from the group consisting of azidothymidine, dideoxyinosine, dideoxycytosine, and d4T.

In a seventeenth aspect, the present invention is directed to a method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with interleukin-2.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described by the following nonlimiting examples which refer to the accompanying Figure 1, short particulars of which are given below.

Figure 1 shows the amino acid and nucleotide sequence of the synthetic gene which encodes the integrase protein reengineered with translation initiation sequences of mammalian cells (Seq ID No.: 1).

DETAILED DESCRIPTION OF THE INVENTION

The term "transdominant" means that the effect of the gene is operational when the gene is expressed from some genetic element not necessarily linked to the virus.

The term "negative" means that the gene reduces replication of the retrovirus.

The term "transdominant negative" means a gene that can inhibit replication of a retrovirus without necessarily being genetically linked to the retrovirus.

The term "transdominant negative integrase gene" includes an intact retroviral integrase gene, fragments thereof, and both active and catalytically inactive mutants thereof.

The term "transfected gene" means a gene introduced into a cell by some exogenous means, such that a gene is added that the cell did not receive from the germ line of the animal from which it was derived.

The term "transient expression" means the expression of a transfected gene that is temporary, usually lasting only a few days.

The term "stable expression" means the expression of a transfected gene where the expression is sustained for weeks.

The term "HIV" includes HIV-1 and HIV-2.

The term "mammal" includes humans.

The present invention includes 293-CD4 cells. Human cells expressing the CD4 gene are generally infectable with HIV, since CD4 is the receptor used by HIV for cell entry. The literature teaches that candidate transdominant negative genes are tested by expressing the transfected gene in a stable cell line, and then testing that stable cell line for its ability to resist infection by HIV (see Yu M., et al., Gene Therapy, 1:13-26 (1994) and references cited therein). Making such a stable cell line expressing the candidate gene is laborious, taking more than 1 month of selection and screening cells for expression.

A faster method would be to use so-called "transient expression" of the candidate gene, where cells are tested within 24-48 hours after transfection. However, in most cell lines, transient expression is inefficient. Inefficiency refers to the percentage of cells in the population that take up and express the gene being introduced. In most cell lines, fewer than 10% and often around 1% of the cells in a population

take up and express the transiently transfected gene. This would clearly be unacceptable for evaluating candidate transdominant negative genes, since if over 90% of a cell population remains untransfected and fully susceptible to HIV infection, a small percentage of resistant cells would not be experimentally detectable.

The present invention solves this problem by introducing the gene for CD4 in an expression vector into the transformed human kidney cell line 293 (available from American Type Culture Collection). This is exemplified in Example 1. The result is a cell line that can be transiently transfected at a frequency of greater than 50%, and by virtue of its CD4 expression, is infectable with HIV. This enables a test of candidate dominant negative genes by transfection and infection a day later.

This is both surprising and unexpected since it could not be predicted that such a cell line would be useful for testing candidate dominant negative genes. Thus, prior to the present disclosure, it was not known that 293-CD4 cells would be infectable with HIV or that the 293-CD4 cells would retain the highly efficient transient expression capability of the 293 cell parent. Moreover, prior to the present disclosure, it was not known that the kinetics of transient expression (e.g., expression of the transfected gene declines after about 2 days) would allow significant protection from an HIV challenge or that protection of 293-CD4 cells from HIV challenge by transient expression would be predictive for protection of a naturally susceptible cell population.

Therefore, the present invention affords a cell line and protocol that can be used to discover the transdominant negative effect of integrase genes; and that will be broadly useful in research on dominant

negative mutants of HIV proteins, as well as other kinds of protective genes such as ribozymes.

Also, the present invention incudes a vector for production of HIV transdominant negative integrase in a mammalian cell incorporating a synthetic integrase gene, e.g., a DNA sequence which contains a substantial number of codons different from the natural codons such as, for example, 10 or more codons different from the natural codons or a fragment thereof that encodes at least 150 amino acids. Preferably, the DNA sequence is Seq ID No.: 1 or a DNA sequence containing 10 or less codons different from Seq ID No.: 1, or a fragment thereof that encodes at least 150 amino acids.

Additionally, the present invention includes transdominant negative retroviral integrase genes and methods to use these transdominant negative integrase genes to render cells resistant to retroviral infection. This would include making a population of cells in an HIV infected person resistant to HIV via delivery of such genes.

The transdominant negative retroviral integrase gene can be introduced into cells by any of the many methods known for introducing DNA into cells, either transiently or permanently. The methods for introducing DNA into cells include calcium phosphate co-precipitation, cationic liposomes, electroporation, receptor mediated endocytosis, particle-mediated gene transfer, or for some cell types, naked DNA can be used. The transdominant negative integrase genes can also be introduced by any of the well-known viral vectors, including retroviruses, adenovirus, adeno-associated virus, and herpes viruses. For some applications, e.g., making an animal resistant to a retrovirus, the transdominant negative integrase might be introduced into the germ line of an animal by the methods for making transgenic animals (including

pronuclear microinjection, embryonic stem cells, and other technologies known in the art). Thus, the transdominant negative integrase gene of the present invention can be introduced into cells by conventional gene transfer technology known to those skilled in the art.

In addition, the transdominant negative integrase gene could be combined with any of the variety of other approaches for gene therapy inhibition of HIV (Yu M., et al., Gene Therapy, 1:13-26 (1994) and Yamada O., et al., Gene Therapy:1:38-45 (1994)).

Thus, the transdominant negative integrase gene may be combined with one or more agents selected from the group consisting of:

a) a transdominant negative gene such as, for example, a transdominant negative rev gene, a transdominant negative tat gene, a transdominant negative gag gene, a transdominant negative env gene, a transdominant negative vpx gene, and the like;

b) a soluble(s) CD4 gene such as, for example, a sCD4 gene, a sCD4-KDEL gene, and the like;

c) an intracellular antibody;

d) an interferon-inducible gene such as, for example, a RBP9-27 gene and the like;

e) a RNA decoy gene such as, for example, HIV-1 TAR, HIV-1 RRE, and the like;

f) an antisense RNA; and

g) a ribozyme such as, for example, a hammerhead ribozyme, a hairpin ribozyme, and the like.

Preferably, a transdominant negative integrase gene of the present invention may be combined with a transdominant negative rev gene such as, for example, a transdominant negative rev M10 gene as described by Malim M.H., et al., Cell, 58:205-214 (1989) and/or a ribozyme that cleaves HIV RNAs. Ribozymes and methods for their preparation have been disclosed in United

States Patent Numbers 4,987,071, 5,037,746, 5,116,742, 5,093,246, and 5,180,818 which are hereby incorporated by reference.

Additionally, specific anti-HIV ribozymes have been disclosed in International Published Patent Applications WO 9401549-A1, WO 9324133-A1, WO 933569-A1, WO 9207065-A1, WO 9201806-A, WO 9110453-A, WO 9103162-A, WO 9013641-A; European Published Patent Application EP 360257-A, and United Stated Patent Number 5,144,019 which are hereby incorporated by reference.

Optimal treatment of a patient receiving dominant negative integrase gene therapy will often involve coadministration with a chemical antiviral drug or interleukin-2. Currently approved drugs that can be combined with integrase gene therapy are azidothymidine, dideoxyinosine, dideoxycytosine, or d4T. The invention envisions combination with future antivirals in the classes of nucleoside and non-nucleoside reverse transcriptase inhibitors, HIV protease inhibitors, and tat inhibitors.

A suitable pharmaceutical delivery method for the dominant negative integrase genes is either by ex vivo or in vivo delivery. In the case of ex vivo delivery, $CD4^+$ T cells, monocytes, or hematopoietic progenitor cells, are removed by plasmapheresis from either the patient or a suitable donor. The dominant negative integrase gene is then introduced into these cells by transduction with a retroviral vector or by microprojectiles (Nabel G., et al., Human Gene Therapy, 5:79-92 (1994)). Alternatively, the genes could be introduced via adeno-associated virus (e.g., Zhou S.Z., et al., J. Exp. Med., 179:1867-1875 (1994)) or liposomes. The transduced cells, either with or without selection for survival of transduced cells, are then administered to the patient to be treated.

Usually a dose of 1×10^7 to 1×10^{11} transduced T cells, or from 1 to 1×10^6 transduced hematopoietic progenitor cells are administered per course of treatment. The patient may be given repeat courses of treatment periodically as required to maintain a suitable level of transduced $CD4^+$ T cells, usually with 3 months to 3 years between treatments.

For in vivo delivery, a suitable viral or nonviral delivery system is used to administer the dominant negative integrase gene to the patient. This administration may be intravenous. The formulation could be, for example, using cationic liposomes (Philip R., et al., J. Biol. Chem., 268:16087-16090 (1993)), where from 10 μg to 10 mg of a vector expressing the dominant negative integrase is delivered. For in vivo administration, it will usually be preferred to use a vector that will direct tissue-specific gene expression, e.g., the promoter of the human CD4 gene.

The following nonlimiting examples illustrate the inventor's preferred methods for preparing a transdominant negative integrase gene of the present invention.

EXAMPLE 1

Construction of 293-CD4 Cells

293 cells are a transformed human cell line (available from the American Type Culture Collection) that are particularly useful for efficient transient expression of transfected genes. The gene for human CD4 (the receptor for HIV) is introduced into these cells to make them susceptible to HIV infection.

Step A Preparation of RSV CD4 Expression Vector

A 3.0 kb fragment containing 1.8 kg of CD4 coding sequence is removed from the T4-pMV7 plasmid (Maddon P.J., et al., Cell, 47:333-348 (1986)) using

EcoRI. The ends are made blunt by Klenow polymerase. The pRSV PAP plasmid (Lin, et al., Biotechniques, 3:344-348, 350-351 (1991)) is cut with HindIII and XbaI to remove the insert, and the ends made blunt with Klenow polymerase. The CD4 fragment is then ligated into the plasmid backbone.

Step B Preparation of 293-CD4 Cells

A calcium phosphate transfection is performed to introduce the RSV-CD4 vector into 293 cells, using the method described in Sambrook J., et al., Molecular Cloning. A Laboratory Manual, Cold Spring Harbor Laboratory Press, 1989, 16.30-16.40. The cells are transfected at 20% confluence, washed with Dulbecco's Modified Eagle's Medium (DMEM) plus 10% fetal calf serum 24 hours posttransfection, and selected in G418 at 0.5 mg/mL 48 hours posttransfection. Following G418 selection, individual clones are isolated and screened by fluorescence activated cell sourcing (FACS) for CD4 using a monoclonal antibody to CD4.

EXAMPLE 2

Construction of a Vector Expressing HIV Integrase in Mammalian Cells Using a Synthetic Gene

The synthetic genes coding for wild-type ("NdeI") and an inactive mutant ("D116N") integrase (IN) had previously been cloned into the *E. coli* expression vector pKK223 (Holler T.P., et al., Gene, 136:323-328 (1993)). Constructs for the NdeI and D116N gene are done in parallel; all manipulations described are done for both genes. The first unique restriction site in the synthetic gene is a ClaI site at nucleotide 17 (relative to the ATG). The plasmid pKK223/NY5IN-NdeI (or D116N) is digested with ClaI and dephosphorylated using bacterial alkaline phosphatase (BRL). Synthetic oligonucleotides ALM 1 (5'-CCAAGCT TGGGCCACC ATG GCC TTC CTG GAC GGT AT-3') and its

complement ALM 2 (5'-CGAT ACC GTC CAG GAA GGC CAT GGT GGC CCA AGC TTGG-3') containing a HindIII site at the 5' end, a ClaI site at the 3' end, and a Kozak consensus (underlined) (Kozak M., Journal of Biological Chemistry, 266:19867-19870 (1991)) for translation initiation are synthesized on an ABI oligonucleotide synthesizer. Following gel purification, the oligos are annealed and the ends of the fragment phosphorylated using T4 polynucleotide kinase (NEB) and ATP. The oligonucleotide pair ALM 1/2 was ligated to the linearized pKK223/NY5IN-NdeI (D116N) and the product of the ligation reaction digested with HindIII, to expose the HindIII site on the 5' end (from the oligos), and to remove the entire IN coding sequence from the bacterial expression vector. The IN gene, optimized for mammalian translation, is isolated from the agarose gel. The sequence of the synthetic gene so modified for translation in mammalian cells (Seq ID No.: 1) is shown in Figure 1. The mammalian expression vector pRcRSV is purchased from Invitrogen. Plasmid pRcRSV is digested with HindIII and the ends dephosphorylated. Linearized plasmid is isolated from an agarose gel. The IN gene is ligated into the HindIII site of pRcRSV to produce the plasmid pRSV/IN-NdeI (D116N). Correct orientation of the insert is determined by restriction endonuclease digestion, and the sequence at the 5' end of the gene (through the ClaI site) confirmed by DNA sequencing.

EXAMPLE 3

Demonstration of Transdominant Negative Activity of Integrase Expression

A vector expressing the synthetic gene of integrase is demonstrated to have dominant negative activity against HIV infection by the following experiment. The integrase gene is transiently

expressed in 293-CD4 cells, which are subsequently infected by HIV. The cells expressing HIV integrase support HIV replication substantially less than cells with no integrase.

The 293-CD4 cells are split into 6-well plates at a cell density of 2-4 $\times 10^5$ per well. Cells are allowed to attach and grow for 6 hours prior to transfections with the expression vector DNAs. Following the protocol of Example 4 for 293 cell transfections, the cells are incubated with calcium phosphate precipitates for 24 hours. The medium on the cells is then changed immediately prior to infection with HIV-1.

4-8 $\times 10^4$ Infectious HIV-IIIB particles are added per well. Infection is allowed to proceed for approximately 12 hours, and then the medium is changed. At various times after infection, samples of medium are removed for reverse transcriptase assay following the protocol of Example 5.

The following data is an example of the counts per minute obtained in the reverse transcriptase assay from samples from such an assay:

Day PostInfection	Vector	pRSV/IN-NdeI
Day 2	1054	1181
Day 3	1280	962
Day 4	2682	1802
Day 5	5607	2792

This, and other experiments, establishes that expression of integrase can substantially slow infection of HIV.

It should be noted that absolute blockage of viral replication cannot be expected in a transient

expression system, since not all of the cells are expressing integrase.

EXAMPLE 4

Protocol for Transfection of 293 Cells

The transfection protocol has been modified for use specifically on 293 and 293/CD4$^+$ cell lines. The same protocol is used for the expression and transdominant experiments to introduce expression vectors. Transfection efficiencies as high as 85-90% are routinely observed.

Solutions		
HBSS:	Dextrose (6 mM)	1.19 g
	NaCl (137 mM)	8.01 g
	KCl (5 mM)	0.37 g
	Na_2HPO_4 (0.7 mM)	0.10 g
	Hepes Na+ (21 mM)	5.47 g
	dissolve in 1000 mL ddH_2O pH solution to 7.05 with NaOH	
2M $CaCl_2$:	29.4 g/100 mL ddH_2O	

Protocol

1. The 293 cell line is split out into appropriate tissue culture dishes.

   Transdominant assay: 6-well plates

   Expression study: 10 cm^2 dishes

   The cells are allowed to adhere and spread for 6 hours prior to transfection.

2. Place 5 μg of vector DNA into 250 μL of HBSS (sufficient for one 6-well or one 10 cm^2 dish). Add 31 μ of 2M $CaCl_2$ and vortex gently for 1 to 2 minutes to thoroughly mix.

3. Incubate at room temperature for 45 minutes; precipitate more than likely will not be visible.
4. Add the $CaPO_4$/DNA precipitate directly to a minimal amount of tissue culture media covering the cells.

   6-well plate: 2 mL/well
   10 cm^2 dish: 5 mL/dish
5. Incubate cells in the presence of precipitate overnight at 37°C. Do not glycerol shock or you will lose the majority of cells.
6. The next morning, aspirate off the old media and replace with new media. Then incubate for the necessary length of time for the experiment.

EXAMPLE 5

Protocol for Reverse Transcriptase Assay

The reverse transcriptase (RT) assay measures the expression of viral proteins in the cultures.

RT reaction cocktail = 1.25 x RT reaction shock		
50 mM	Tris pH 8.3	10 mL 1M
75 mM	KCl	15 mL 1M
10 mM	$MgCl_2$	2 mL 1M
10 mM	DTT	2 mL 1M
1 mM	EGTA	76 mg
0.5%	NP-40	1 mL 10%
100 µg/mL	poly rA	2 mL 10 mg/mL
25 µg/mL	oligo dT 100 A_{260} units (1 bottle)	128 mL dH_2O

8 µCi/mL ^{32}P-dATP (400 Ci/mmol) is added immediately before assay.

Protocol

1. Place two GeNunc polypropylene modules (120 μL, Cat #2-32549) in a GeNunc frame (Cat #2-32042) for each assay plate.
2. Transfer 5 μL of culture media from each well of the assay plate to the corresponding well of the GeNunc module. Using a 12-channel pipettor, transfer row H, change tips, and complete the rest of the plate starting at row A and moving to row G. By moving from the lowest to highest RT activity, the rest of the plate can be transferred without changing tips.
3. Prepare 2.5 mL RT reaction cocktail for each plate by adding 2.5 μL ^{32}P-dATP (400 Ci/mmol, 10 μCi/μL) to 2.5 mL 1.25 x RT reaction stock.
4. Dispense 2.5 mL RT reaction cocktail into the trough of an 8-channel reagent reservoir for each assay plate. Use a P1,000 pipetman so that the radioactive tip can be discarded in the Ziplock waste bag.
5. Add 20 μL RT reaction cocktail to each well of the GeNunc module. Using a 12-channel pipettor, transfer row H, change tips, and finish the rest of the plate stating at row A and moving to row G. By moving from the lowest to highest RT activity, the rest of the plate can be filled from one trough of the reagent reservoir without changing tips.
6. Cover the wells with GeNunc adhesive tapes (Cat #232700).
7. Incubate 2 hours, 37°C.
8. Mark a 96-well array on a sheet of Whatman DE81 anion exchange filter paper using the rubber stamp.
9. Spot 4 μL of the RT reaction from each well of the GeNunc module onto the corresponding mark of the

DE81 filter. Using a 12-channel pipettor, transfer row H, change tips, and finish the rest of the module starting at row A and moving to row G. By moving from the lowest to highest RT activity, the rest of the module can be spotted without changing tips.

10. Wash the filter five times, 3 minutes each, in 2 × SSC (300 mM NaCl, 30 mM NaCitrate, pH 7).
11. Rinse the filter twice in 95% ethanol.
12. Air dry the filter.
13. Quantitate the RT activity by counting the incorporated ^{32}P for each well using the Betagen Betascope 603 with the slot/dot blot analysis program as described in the applications manual.

Data is collected for 30 minutes in the ^{32}P mode and reported as total counts per well.

EXAMPLE 6

Construction of a CEM Cell Line Expressing HIV-1 Integrase

CEM cells are a line of $CD4^+$ human lymphoblastoid cells (obtainable from American Type Culture Collection). CEM cells were maintained in RPMI 1640 medium supplemented with 10% fetal calf serum, 50 U/mL penicillin, 50 U/mL streptomycin. All tissue culture reagents were obtained from Gibco BRL, Gaithersburg, MD. CEM cells were transfected by electroporation according to the method of Aldovini and Feinberg (pp. 147-159 in: Techniques in HIV Research, Stockton Press, New York, NY, 1990). Twenty micrograms each of plasmid DNA (either pRc/RSV, pRSV/IN-Nde, or pRSV/IN-D116N) were added to a 0.4 mL suspension of 5 million CEM cells in serum free RPMI 1640 medium. The DNA-cell suspensions were incubated on ice for 10 minutes in a Gene Pulsar cuvette and then subjected to a single pulse of 960 μF at 300 volts using a

Bio-Rad Gene Pulsar Electroporator (Bio-Rad, Richmond, CA). Following electroporation, the cells were incubated on ice for 10 minutes and then diluted in 10 mL RPMI 1640 medium with 10% fetal calf serum. The cells were incubated in 75 cm^2 tissue culture flasks at 37°C in a 5% CO_2 incubator for 48 hours. The cells from each flask were centrifuged to pellet the cells and the supernatants removed. The cell pellets were diluted in RPMI 1640 medium supplemented with 10% fetal calf serum and 750 μg/mL G418 (Geneticin, Gibco BRL) at a density of 200,000 cells per mL. The diluted cells were transferred to 96 well plates, 100 μL/well, and incubated at 37°C for 7 days. The G418 selection was then increased to 1 mg/mL. Colonies appeared in 2-3 weeks. These colonies were transfered to 6 well plates and were diluted in 3 mL RPMI 1640 medium plus 1 mg/mL G418.

After the cells had reached a density of 1,000,000 cells per mL, they were screened by western blot techniques for expression of HIV-1 integrase, using a polyclonal rabbit antiserum prepared against integrase produced in *E. coli* (Holler T.P., et al., Gene, 136:323-328 (1993)). The procedure used for this western blot is described. One million cells were suspended in Laemmli buffer, and loaded onto a 12% polyacrylamide gel. The separated protein bands were transferred to nitrocellulose paper by electroblotting. The blots were blocked with 10% nonfat dry milk in phosphate buffered saline (PBS) plus 0.3% tween 80 for 1 hour. The blocked blots were then incubated for 2 hours with a 1/1000 dilution of the rabbit antiserum. The blots were then washed 3 times in PBS/tween, then incubated for 1 hour with a 1/2000 dilution of goat antirabbit IgG conjugated with horseradish peroxidase. After 4 washes in PBS-tween, the integrase expression was detected with an enhanced chemiluminescence (ECL)

kit (Amersham, Arlington Heights, IL). Of 50 wells which grew under G418 expression, two each expressing wild type integrase or D116N were obtained.

EXAMPLE 7

Demonstration of Protection Against HIV Infection in CEM Cells Expressing a Dominant Negative Integrase Gene

CEM cell lines prepared in Example 6 were grown in the presence of 1 mg/mL G418, and density adjusted to 4×10^6 cells/mL. Fifty microliters of suspended cells was combined with 40 μL HIV stock virus (2×10^3 pfu/mL) and 10 μL medium. Cells and virus were coincubated at 37°C for 2 hours, then washed once in 1 mL medium. Each washed pellet was resuspended in 3 mL medium, then 1 mL aliquots were plated in triplicate wells of a 24 well plate. Fifty microliter samples were taken from each well of infected cells on days 1-5 and 7 postinfection. Cell cultures were split 1:3 on days 3 and 5 after sampling, by adding 2 mL medium, mixing the culture, then removing 2 mL of medium and infected cells. The data is not corrected for these splits.

The samples were assayed using the reverse transcriptase assay described in Example 5. The counts per minute from the triplicate samples at each time point were averaged.

Day	Control Vector	Nde	D116N
1	598	2325	2035
2	1177	1701	1905
3	1947	1806	2260
4	6776	3102	3396
5	6815	2768	2935
7	22922	9820	7542

This experiment shows that expression of either the wild type integrase (Nde) or the D116N mutant retards the growth of HIV-1 in a human lymphoblastoid cell line, as predicted by the results in the 293-CD4 cells.

It should be noted that since these cells were not cloned before testing, even though all were G418 resistant, not all of them were expressing integrase. Therefore, the level of protection observed is a minimal level to be expected in a population expressing the dominant negative integrase genes.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Holler, Tod Paul
Meyer, Annette
Nabel, Gary Jan
Post, Leonard

(ii) TITLE OF INVENTION: Method of Using Transdominant Negative Retroviral Integrase in the Treatment of Retroviral Infection

(iii) NUMBER OF SEQUENCES: 1

(iv) CORRESPONDENCE ADDRESS:
(A) ADDRESSEE: Warner-Lambert Company
(B) STREET: 2800 Plymouth Road
(C) CITY: Ann Arbor
(D) STATE: MI
(E) COUNTRY: US
(F) ZIP: 48105

(v) COMPUTER READABLE FORM:
(A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Ver #1.25

(vi) CURRENT APPLICATION DATA:
(A) APPLICATION NUMBER: US
(B) FILING DATE:
(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Tinney, Francis J.

(B) REGISTRATION NUMBER: 33069

(C) REFERENCE/DOCKET NUMBER: PD-5082

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: 313 996-7295

(B) TELEFAX: 313 996-1553

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 900 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

CCAAGCTTGG GCCACCATGG CCTTCCTGGA CGGTATCGAT AAAGCTCAGG
AAGAACACGA 60

AAAATACCAC TCTAACTGGC GCGCCATGGC TTCTGACTTC AACCTGCCGC
CGGTTGTTGC 120

CAAGGAAATC GTGGCTTCTT GCGACAAATG CCAATTGAAA GGTGAAGCTA
TGCATGGTCA 180

GGTCGACTGC TCTCCAGGTA TCTGGCAGCT GGACTGCACT CATCTCGAGG
GTAAAGTTAT 240

CCTGGTTGCT GTTCACGTGG CTTCCGGATA CATCGAAGCT GAAGTTATCC
CGGCTGAAAC 300

CGGTCAGGAA ACTGCTTACT TCCTGCTTAA GCTGGCCGGC CGTTGGCCGG
TTAAAACTGT 360

TCACACTGAC AACGGTTCTA ACTTCACTAG TACTACTGTT AAAGCTGCAT
GCTGGTGGGC 420

CGGCATCAAA CAGGAGTTCG GGATCCCGTA CAACCCGCAG TCTCAGGGCG
TTATCGAATC 480

TATGAACAAA GAGCTCAAAA AAATCATTGG CCAGGTACGT GATCAGGCTG
AGCACCTGAA 540

AACCGCGGTG CAGATGGCTG TTTTCATCCA CAACTTCAAA CGTAAAGGTG
GTATCGGTGG 600

TTACAGCGCT GGTGAACGTA TCGTTGACAT CATCGCTACT GATATCCAGA
CTAAAGAACT 660

GCAGAAACAG ATCACTAAAA TCCAGAACTT CCGTGTATAC TACCGTGACT
CTAGAGACCC 720

GGTTTGGAAA GGTCCTGCTA AACTCCTGTG GAAGGGTGAA GGTGCTGTTG
TTATCCAGGA 780

CAACTCTGAC ATCAAAGTGG TACCGCGTCG TAAAGCTAAA ATCATTCGCG
ACTACGGCAA 840

ACAGATGGCT GGTGACGACT GCGTTGCTAG CCGTCAGGAC GAAGACTAAA
AGCTTCAGGC 900

CLAIMS

1. A method of using a transdominant negative integrase gene to make at least one cell resistant to a retroviral infection.

2. The method of Claim 1 wherein the cell is selected from the group consisting of a mammalian cell and an avian cell.

3. The method of Claim 2 wherein the mammalian cell is a human cell.

4. The method of Claim 1 wherein the retroviral infection is selected from the group consisting of: HIV; HTLV I; HTLV II; equine infectious anemia virus; bovine leukemia virus; murine retrovirus; and avian leukosis virus.

5. The method of Claim 4 wherein the retroviral infection is HIV.

6. A method for introducing a transdominant negative integrase gene into at least one mammalian cell to make said cell resistant to a retroviral infection, comprising introducing the DNA into at least one mammalian cell by a process of delivery selected from the group consisting of:

a) use of calcium phosphate co-precipitation;
b) in a complex of cationic liposomes;
c) electroporation;
d) receptor mediated endocytosis;
e) naked DNA;
f) transduction by a viral vector; and
g) particle-mediated gene transfer.

7. The method of Claim 6 wherein the transdominant negative integrase gene is HIV integrase.

8. The method of Claim 6 wherein the mammalian cell is a human cell.

9. The method of Claim 8 wherein the human cell is a $CD4^+$ T lymphocyte or a monocyte.

10. The method of Claim 8 wherein the human cell is a hematopoietic progenitor cell.

11. The method of Claim 6 wherein the viral vector is selected from the group consisting of: retrovirus; adenovirus; adeno-associated virus; and herpes virus.

12. A method for introducing a transdominant negative integrase gene into at least one mammalian cell to make said cell resistant to a retroviral infection comprising inserting said transdominant negative integrase gene into a vector and expressing transdominant negative integrase in said at least one mammalian cell.

13. The method of Claim 12 wherein the transdominant negative integrase gene is HIV integrase.

14. The method of Claim 12 wherein the mammalian cell is a human cell.

15. The method of Claim 14 wherein the human cell is a $CD4^+$ T lymphocyte or a monocyte.

16. The method of Claim 14 wherein the human cell is a hematopoietic progenitor cell.

17. The method of Claim 12 wherein the vector is selected from the group consisting of: pRSV/IN-NdeI and pRSV/IN-D116N.

18. The method of Claim 17 wherein the vector is pRSV/IN-NdeI.

19. The method of Claim 12 wherein the mammalian cell is 293-CD4.

20. A method of constructing the pRSV/IN-NdeI vector comprising inserting the HIV integrase gene into the pRcRSV vector to afford the pRSV/IN-NdeI vector.

21. A vector for production of HIV transdominant negative integrase comprising a DNA sequence encoding HIV integrase.

22. A vector according to Claim 21 selected from the group consisting of pRSV/IN-NdeI and pRSV/IN-D116N.

23. A vector according to Claim 22 which is pRSV/IN-NdeI.

24. The vector of Claim 21 wherein the DNA sequence contains a substantial number of codons different from the natural codons.

25. The vector of Claim 24 wherein the DNA sequence contains 10 or more codons different from the natural codons.

26. The vector of Claim 21 wherein the DNA sequence is Seq ID No.: 1.

27. The vector of Claim 21 wherein the DNA sequence contains 10 or less codons different from Seq ID No.: 1, or a fragment thereof that encodes at least 150 amino acids.

28. The vector of Claim 21 for production of HIV transdominant negative integrase in a eukaryotic cell.

29. The vector of Claim 28 for production of HIV transdominant negative integrase in a mammalian cell.

30. The synthetic gene having Seq ID No.: 1.

31. A synthetic gene having a DNA sequence containing 10 or less codons different from Seq ID No.: 1 or a fragment thereof that encodes at least 150 amino acids.

32. A highly transfectable cell line which is transduced to express human CD4.

33. A cell line according to Claim 32 which is 293-CD4.

34. A method of constructing a 293-CD4 cell comprising inserting the CD4 coding sequence into a vector and transfecting the vector into 293 cells.

35. The method of Claim 34 wherein the vector is RSV-CD4.

36. A method of preparing a retroviral integrase comprising inserting a synthetic integrase gene

into a vector and expressing said vector in a mammalian cell.

37. The method of Claim 36 wherein the retroviral integrase is HIV integrase.

38. The method of Claim 36 wherein the synthetic integrase gene contains a substantial number of codons different from the natural codons.

39. The method of Claim 38 wherein the DNA sequence contains 10 or more codons different from the natural codons.

40. The method of Claim 36 wherein the DNA sequence is Seq ID No.: 1.

41. The method of Claim 36 wherein the DNA sequence contains 10 or less codons different from Seq ID No.: 1, or a fragment thereof that encodes at least 150 amino acids.

42. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene.

43. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with one or more agents selected from the group consisting of:

a) as transdominant negative rev gene;
b) as transdominant negative tat gene;
c) a transdominant negative gag gene;
d) a transdominant negative env gene;

e) a transdominant negative vpx gene;
f) a sCD4 gene;
g) a sCD4-KDEL gene;
h) an intracellular antibody;
i) a RBP9-27 gene;
j) a HIV-1 TAR gene;
k) a HIV-1 RRE gene;
l) an antisense RNA;
m) a hammerhead ribozyme; and
n) a hairpin ribozyme.

44. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a transdominant negative rev gene.

45. The method of Claim 44 wherein the transdominant negative rev gene is rev M10.

46. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a ribozyme that cleaves HIV RNA.

47. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with a transdominant negative rev gene and a ribozyme that cleaves HIV RNA.

48. A pharmaceutical delivery method adapted for administration to a patient in an effective amount of an agent for treating a retroviral infection

comprising a transdominant negative integrase gene and a suitable viral or nonviral delivery system.

49. A pharmaceutical delivery method according to Claim 48 adapted for ex vivo or in vivo delivery.

50. A pharmaceutical delivery method according to Claim 48 directed to therapeutic or prophylactic administration.

51. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with an antiviral agent.

52. The method according to Claim 51 wherein the antiviral agent is selected from the group consisting of a nucleoside or a nonnucleoside reverse transcriptase inhibitor, a HIV protease inhibitor, and a tat inhibitor.

53. The method according to Claim 52 wherein the reverse transcriptase inhibitor is selected from the group consisting of azidothymidine, dideoxyinosine, dideoxycytosine, and d4T.

54. A method of treating AIDS in a patient comprising administering to said patient a therapeutically effective amount of a transdominant negative integrase gene in combination with interleukin-2.

CCAAGCTTGGGCCACCATGGCC TTCCTGGACGGT ATCGATAAAGCTCAGGAAGA ACACGAAAAATACCACTCTA ACTGGCGCGCCATGGCTTCT
GACTTCAACCTGCCGCCGGT

TGTTGCCAAGGAAATCGTGG CTTCTTGCGACAAATGCCAA TTGAAAGGTGAAGCTATGCA TGGTCAGGTCGACTGCTCTC CAGGTATCTGGCAGCTGGAC
TGCACTCATCTCGAGGGTAA

AGTTATCCTGGTTGCTGTTC ACGTGGCTTCCGGATACATC GAAGCTGAAGTTATCCCGGC TGAAACCGGTCAGGAAACTG CTTACTTCCTGCTTAAGCTG
GCCGGCCGTTGGCCGGTTAA

AACTGTTCACACTGACAACG GTTCTAACTTCACTAGTACT ACTGTTAAAGCTGCATGCTG GTGGGCCGGCATCAAACAGG AGTTCGGGATCCCGTACAAC
CCGCAGTCTCAGGGCGTTAT

CGAATCTATGAACAAAGAGC TCAAAAAAATCATTGGCCAG GTACGTGATCAGGCTGAGCA CCTGAAAACCGCGGTGCAGA TGGCTGTTTTCATCCACAAC
TTCAAACGTAAAGGTGGTAT

CGGTGGTTACAGCGCTGGTG AACGTATCGTTGACATCATC GCTACTGATATCCAGACTAA AGAACTGCAGAAACAGATCA CTAAAATCCAGAACTTCCGT
GTATACTACCGTGACTCTAG

AGACCCGGTTTGGAAAGGTC CTGCTAAACTCCTGTGGAAG GGTGAAGGTGCTGTTGTTAT CCAGGACAACTCTGACATCA AAGTGGTACCGCGTCGTAAA
GCTAAAATCATTCGCGACTA

CGGCAAACAGATGGCTGGTG ACGACTGCGTTGCTAGCCGT CAGGACGAAGACTAAAAGCT TCAGGC

FIGURE 1

INTERNATIONAL SEARCH REPORT

National Application No
PCT/US 95/09110

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/48 C12N15/55 A61K48/00 C12N15/86 C12N5/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C07K A61K C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	AIDS RES HUM RETROVIRUSES, JUN 1992 V8 N6 P 1013-1022, FEINBERG MB ET AL 'Intracellular immunization: trans-dominant mutants of HIV gene products as tools for the study and interruption of viral replication.' see the whole document ---	1-41
Y	PROC NATL ACAD SCI U S A, OCT 15 1992, 89 (20) P9870-4, UNITED STATES, BEVEC D ET AL 'Inhibition of human immunodeficiency virus type 1 replication in human T cells by retroviral-mediated gene transfer of a dominant-negative Rev trans-activator.' see the whole document --- -/--	1-41

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 October 1995	30. 11. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gurdjian, D

INTERNATIONAL SEARCH REPORT

ıational Application No
PCT/US 95/09110

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GENE, vol. 136, 1993 pages 323-328, T.P.HOLLER ET AL. 'Hiv1 integrase expressed in E.coli from a synthetic gene' see the whole document ---	1-41
A	ARCH VIROL, 1993, 131 (1-2) P177-83, AUSTRIA, RODNER B ET AL 'Expression of a processed and a non-processed form of the integrase protein of HIV-1 in the baculovirus system.' see the whole document ---	1-41
A	CELL, OCT 6 1989 V59 P113-120, TRONO D ET AL 'HIV-1 Gag mutants can dominantly interfere with the replication of the wild-type virus.' see the whole document ---	1-41
A	WO,A,92 03578 (US ARMY) 5 March 1992 see abstract ---	1-5
A	US,A,5 217 889 (RONINSON IGOR B ET AL) 8 June 1993 see column 1, paragraph 3 - column 2, paragraph 4 see column 9, line 9 - line 13 -----	1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/09110

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 42-54
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 42-54 are directed to a method of treatment of the human body the search has been carried out and based on the alleged effects of the composition.

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No
PCT/US 95/09110

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